EFFECT OF AEROBIC AND ANAEROBIC CONDITIONS ON THE ION UPTAKE OF RICE[1]

(Physiological study of the rice II.)

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It is well-known that there is a close correlation between the nutrient uptake and the presence of O_2. The greater part of the examinations concerning the role of O_2 played in the ion absorption of the root has been carried out in water culture. All the experiments prove that the aeration of the nutrient solution considerably enhances the ion uptake. The precise process of the ion uptake, in spite of the numerous investigations, is still unkown. One of the most commonly accepted concepts of the ion uptake is that of LUNDEGARDH (3) whereby the uptake of the anions is an active process requiring energy, while the cations get passively into the cells, strictly according to the electrostatical laws.

LUNDEGARDH's original classical scheme for ion uptake assumes the formation of an O_2 gradient between the surface of the root and the central tissue cylinder, i. e. the concentration of O_2 progressing from the outer medium, is gradually decreasing in the tissues of the root. In rice due to the flooding anaerobic conditions are formed within a few days in the environment of the root (14), consequently the above-mentioned gradient O_2 can not be formed. The present paper aims not at expounding in details the various theories, so much however, has to be mentioned that in the case of rice LUNDEGARDH's earlier described scheme, concerning the ion uptake is hardly conceivable. LUNDEGARDH's concept has been further developed, some authors refuted, several new similar (3, 4) and different theories were put forward. In one respect, however, almost every theory agrees i. e. the prerequisite of the process is the presence of O_2 (5, 6, 11, 15).

Studying the nutrient uptake it was pointed out that the O_2 requirement of certain plants is different and in many a case not the partial pressure of O_2 but the speed of its diffusion is decisive whereon the continuous supply depends. It was found that numerous species are able — though slowly — to take up nutrients, grow respectively even in an evironment at 0,5 % level of O_2.

1. The experiments were made in the *Alsógöd* Biological Station of the EÖTVÖS University of Sciences in Budapest.

There are such plants where practically anaerobic conditions prevail in the enviroment of the root. Here belong firstly the aquatic and marshy plants of which the rice plant is very important. As it is well-known the rice plants — anyhow the sorts grown in this country — require irrigation for the most part of their growing period. In the soil anaerobic conditions are formed within a few days following the flooding (14).

Bearing in mind that the life processes in the roots are generally bound to the presence of O_2, the question arises whether the O_2 of the environment is needed to the ion uptake and incorporation in the rice root under the anaerobic conditions formed in the rice fields, i. e. in what way the ion uptake occurs. The literature relating to this subject-matter is fairly incomplete and in many cases is contradictory (12, 18). The experiments refer but to certain fragmentary examinations (1, 16) and no efforts have made to try to find a connection between the characteristics of the metabolism and the ion uptake of the rice-root. Generally the uptake of such ions has been examined which are analytically easily determined but for the time being they have no decisive significance in the metabolism of the plants.

The present paper aims at the elucidation of the role of O_2 played in the nutrient up-take, namely in the N and P up-take partly under aerobic and partly anaerobic conditions. Account relating to the role plaved by the O_2 of the enviroment in the incorporation of the substance will be given in an other paper.

Material and method

The experimental plants were grown in half sterile sand culture. The seeds before being sown were swollen, i. e. pre-germinated in petri dishes till the bursting of the seed-coats. Till germination of the seeds a moisture corresponding to 80 % water capacity of the sand was secured, then followed a shallow flooding. Both the roots and the overground organs of the rice-plants treated in this way developed well.

After the heterotrophic stage the plants were placed from sand in HOAGLAND's nutrient solution. For control, barley was grown under identical circumstances but without flooding. Inference to the ion up-take was made on the basis of the consumption of the culture medium comparing the P and N content of the culture medium at the beginning and end of the experiment. The concentration of the culture medium and time of the experiment were chosen so that the single elements should be present also at the end of the experiment in measurable quantity. The P was determined with FISKE—SUBAROV's method and the NH_3—N photometrically with Nesslerization.

The aerobic and anaerobic conditions in the culture were secured by bubbling air and nitrogen gas respectively. The bacterial infection has been taken into consideration in every case, consequently the duration of the experimental time in the same culture was maximally 8 hours. 50 plants were used in the examinations, repeated thrice. The temperature during the experiment fluctuated between 20—22 C°.

Experimental results

Firstly the uptake of the two important nutrients i. e. N and P was examined. As it is seen in *Fig. 1.* in the barley the aeration favourably influences the nutrient solution, due to the anaerobic conditions formed, considerably inhibits the pu-take of both P and N. In the case of the rice the

effect of aeration is not positive at all, simultaneously the ion up-take is not inhibited by the anaerobic conditions either. So a considerable difference is shown between the aerobic and anaerobic circumstances in the ion up-take of barley and rice.

This experiment was repeatedly carried out on different sorts of rice in order to see the possible differences between. According to the data of *Fig. 2—3* the different sorts react in almost the same way to the aerobic and anaerobic conditions respectively.

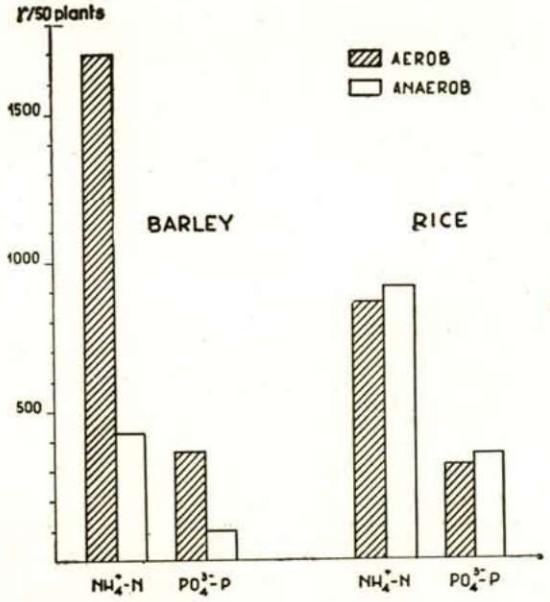

Fig. 1. Effect of aerobic and anaerobic conditions on the ion up-take of barley and rice

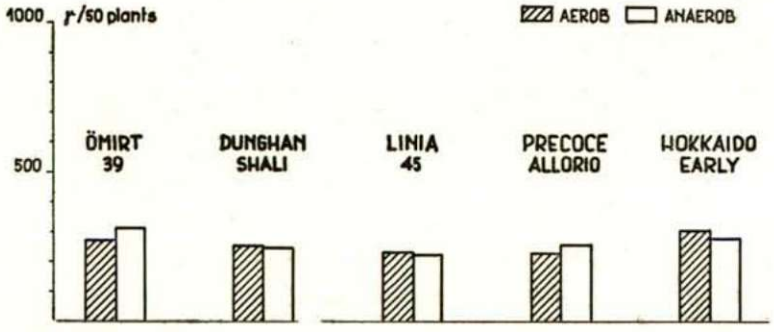

Fig. 2. Effect of aerobic and anaerobic conditions on the PO_4-P up-take of different rice sorts

In a single sort — *Linia 45* — could be noted a small, favourable effect of the oxygen bubbling.

The removal of the overground organ or its flooding changes the conditions of the ion up-take. Under anaerobic circumstances the ion up-take of the roots deprived of their shoots gradually decreases proportionately the

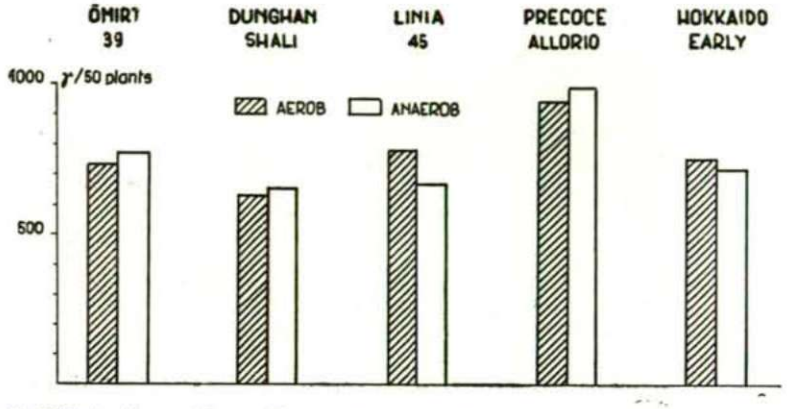

Fig. 3. Effect of aerobic and anaerobic conditions on the NH_4-N up-take of different rice sorts

time, and at the same time the aeration favourably effects the nutrient up-take *(Table 1.)*

Tab. 1. The effect of the extent of the immersion on the ion up-take of rice

	Extent of immersion	NH_3-N up-take γ/6 hours	
		bubbled with air	bubbled with nitrogen
1	Only the root immersed in the culture solution	521	562
2	About 2/3 of the overground shoot immersed in the culture	666	513
3	Plant totally immersed	586	286
4	Root deprived of the overground shoots in the culture	426	73

The ion up-take of water-logged rice-plants in aerated medium seems to be favourable, however, other life-processes as it will be later pointed out, are not be considered optimal. The nutrient up-take of completely water-logged plants in anaerobic medium is intensively inhibited.

Evaluation of results

Comparing the experimental results and the literary data naturally the question arises of the rice essentially be a plant in need of O_2 or in contrast to other plants it requires anaerobic conditions in the environment of the roots.

As we have seen in intact plants the aeration did not prove to have positive effect *(Fig. 1—2—3)*. On this basis the eronneous conclusion may be drawn that the rice is a plant not requiring O_2. By removing the overground organ the conditions for the up-take were completely changed which drew our attention partly to the O_2 requirement, partly to the important role of the shoot.

As the root can not get the oxygen needs from its immediate environment, likely this task is carried out for the most part by the overground organs. On the basis of these considerations our experimental results can be well explained. The ineffectiveness of both aerobic and anaerobic conditions in intact plants and the favourable effect of aeration in the case of roots deprived of the shoot, can be interpreted by the fact if the oxygen transport of the shoot is sufficient the metabolic processes of the roots are insignificantly influenced by the oxygen conditions of the environment. The anaerobic circumstances may be indirectly injurious to the rice (2) when the toxic substances disturbing the metabolic processes are accumulated in the immediate vicinity of the root.

It is well-know that in the root, shoots and leaves of the rice plants large intercellulars i. e. aerenchymes are found which secures partly the floating and partly the oxygen supply. The latter seems to be decisive in the case of rice as indicated by our anatomical *(Fig. 4, 5* and *Table 1)*.

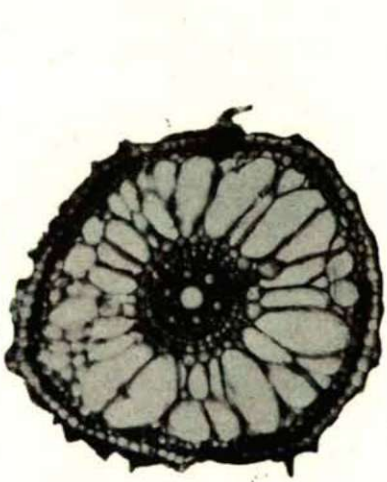

Fig. 4. Cross-section of rice root

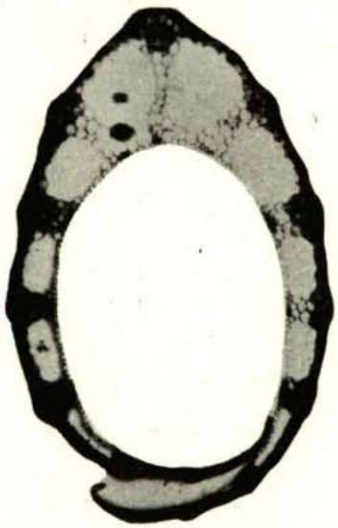

Fig. 5. Cross-section of rice leaf-sheath

These experimental data confirm the assumption that the oxygen is required not alone for the germination of the rice as explained by ERÜGEN (7) but also in later developmental stages. Thus the earlier concept that rice is a plant requiring no oxygen, is wrong.

Practically it is known that the stagnant oxygen-poor water, especially in case of high irrigation is unfavourable for the rice (17). On the basis of our experiments may be explained so that partly the oxygen transport in the

shoots is rendered difficult partly the irrigation water may produce metabolic disturbance in the rice-plants consequently the equilibrium of the biochemical processes is disturbed and the hydrolytic processes prevail.

This phenomenon raises a problem very interesting both theoretically and practically, namely why is irrigation essentially needed for the rice as it can be considered neither a water- nor a marshy plant (17). In this respect the literature offers very few references and explanations and so the question can be still considered open (10).

Bearing in mind the results of our experiments it can be stated that every such agrotechnical procedure like high irrigation following germination, giving preference to other view-points e. g. weeding, is unable to secure the necessary aerobic conditions for the young plants may have an injurious and inappropriate effect on the further development of the rice.

Summary

The roots of the rice can not fully obtain its O_2 requirement from enviroment. The anaerobic conditions due to the flooding bring about a special situation in the mineral nutrition of the rice whereof several problems are to be still cleared up. Our experimental results from examinations of young plants support the concept that aerobic or anaerobic conditions respectively, at the level of the root, do not affect the intensity of N and P up-take in intact plants. Removing or immersing the shoot the aeration will turn to positive effect, consequently the biological processes occurring in the rice-root and directly related to the nutrient up-take are in need of O_2. If the supply of O_2, due to high irrigation, is not sufficient, the ion up-take is unfavourably affected. High flooding is unfavourable from view point of up-take but particularly from that of incorporation even in medium rich in O_2.

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